Agricultural Technology in Early Medieval India (c. A.D. 500–1300)

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The article discusses the spread of agriculture to an unprecedented degree in the period from c. A.D. 500 to 1300 (early medieval times) on the basis of both epigraphic and textual materials that also speak of considerable diversity of crops, including what may be considered as cash crops. The author pays attention to the role of metal—especially iron—technology in the development of agriculture during this period. It also argues for betterment in manuring. Inseparably associated with the expansion of agriculture—as an impact of the issuance of profuse number of land grants—are better irrigation technologies. The diversity of irrigation techniques and hydraulic projects, local and supra-local, had intimate linkages with the variability of access to precious water resources in disparate areas of the subcontinent. In this connection, the article also offers early Indian perceptions of the monsoons; it also seeks to underline the meteorologists' observations of the correlation between the flood-level in the Nile catchment area (by the use of the Nilometer) and the pattern of rainfall in the subcontinent on a long chronological range.

The long history of India's dependence on agriculture spans across millennia, beginning from the earliest farming community at Mehrgarh (in Quetta area, Pakistan), datable to c. sixth–fifth millennium B.C.[1] This

[1] Jarrige, 'Excavations at Mehrgarh'. G.R. Sharma and his colleagues claim that the earliest possible cultivation of the domesticated variety of rice was traced at the Mesolithic site of Koldihawa (in eastern UP), dated to c. seventh millennium B.C. See Sharma et al.

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however does not imply that the vast subcontinent experienced sedentary agrarian society right from such a remote time. The chalcolithic settlements in different parts of the subcontinent were associated with farming communities which depended on copper and bronze tools and also lithic implements for agricultural and crafts production.[2] Gordon Childe analysed how the bronze technology helped the development of the first urban society in the subcontinent, namely the Harappan Civilisation (c. 2600–1750 B.C.).[3] A significant amount of literature exists on the question of the introduction of iron technology in India roughly since c. 800 B.C. Iron technology has been thought to have been largely instrumental in clearing the dense vegetation cover in the Ganga valley with iron axes and adzes. Iron ploughshares are perceived to have brought significant change in the ploughing techniques of the alluvial soil which is heavier and thicker than the soil in the Punjab and the Indo–Ganga divide. Iron implements, to begin with, were profusely used as weapons by the incipient states in the Ganga valley from the eighth–seventh centuries B.C. onwards. Both textual and field archaeological evidence is available on the development of iron technology for productive purposes and military needs. The Ganga valley in the period between the sixth and fourth centuries B.C. experienced the emergence of both urban centres and territorial polities (*janapadas/mahajanapada*s); the period c. 200 B.C.–A.D. 300 is noted for the spread of the monarchical state system and urban society beyond the Ganga valley and north India into the peninsular part.[4] A large number of historians and archaeologists, many of them Marxists, have argued for the crucial role of iron technology in agriculture in ensuring an agricultural surplus which was considered an essential prerequisite for both the state and the city formations during c. 600 B.C.–A.D. 300.[5] Though the importance of surplus in the making of the monarchical

The Beginnings of Agriculture: 135–37. Habib, 'The Peasant in Indian History' approvingly cites this evidence. In his more recent *Prehistory*, Habib however considers that the Koldihawa evidence by Sharma is too high an overdating.

[2] Allchin and Allchin, *The Rise of Civilization*; also Chakrabarti, *India, An Archaeological History*.

[3] Childe, *What Happened in History?*; for the agrarian life in the Harappan Civilisation see Ratnagar, *Understanding Harappa*.

[4] Thapar, *From Lineage to State*; Sharma, *Social and Economic History of Early India,* and *Material Culture*; Allchin et al., *Early Historic South Asia*.

[5] Banerji, *The Iron Age*; Kosambi, *Culture and Civilization*; Sharma, *Material Culture*.

polity and urban society has been recognised, the primacy of iron technology as a contributive factor to state and urban formations has been strongly contested.[6] The debate largely revolves around the question of whether agrarian surplus was essentially a technological product (that is, an outcome of the more efficient iron technology) or whether it was the social and political demand for the surplus and the existence of a political structure that was the most important engine of change. Metal, especially iron, technology became more widespread in India since the fourth century A.D. One of the greatest examples of huge strides made in iron technology is indeed the inscribed iron pillar at Mehrauli (in Delhi), which was manufactured probably in the fifth century and has so far remained free from rust. No less spectacular, on the other extreme of the chronological spectrum, is the use of the iron beam in the thirteenth-century Gundichabari temple near Puri (in Orissa). R.S. Sharma has drawn our attention to six varieties of iron manufactured in eastern India, according to the *Paryayamuktavali* (twelfth century).[7] Different varieties of iron also figure in the list of commodities exported overseas from the Kanarese and Malabar littorals to Aden, according to the business letters of Jewish merchants (eleventh to thirteenth centuries).[8] Along with this, the period c. 500–1300 certainly witnessed manifold growth in copper and bronze technology. One of the demonstrable markers of the latter technological development was the immensely large number of copper plate land grant charters and bronze sculptures.

What one cannot miss in the history of India during A.D. 500–1300 is the remarkable proliferation of political powers, mostly regional and local—though none of them achieved pan-Indian paramountcy (like the Mauryan empire). In a predominantly agrarian country like India, the spread of the monarchical polity has a clear linkage with the expansion of agrarian settlements which provide the principal resource base of these polities.[9] The best empirical demonstration of the agrarian/rural expansion in early medieval India comes in the form of a vast number of land grant records. These land grants, mostly inscribed on copper plate charters or

[6] Chakrabarti, *Theoretical Issues* and *Ancient Indian Cities*; Ghosh, *The City in Early Historical India*.

[7] Sharma, 'How Feudal Was Indian Feudalism?'

[8] Goitein, *Letters*, especially a letter of 1139.

[9] Kulke, *The State in India*; also see *Studies in History*, vol. IV, 1982, for significant essays on the formation of the state in early medieval India.

on the temple walls (in south India), recorded transfer of revenue-free landed property (*agrahara/brahmadeya/devadana*) by royal/administrative order, usually in favour of religious donees (a single brahmana, a group of brahmanas, a Buddhist monastery, a Brahmanical temple or *matha*, a Jaina establishment, etc.) on a perpetual basis (*akshayanivi*).[10] The majority of such revenue-free landed property transfers were located in hitherto uncultivated, fallow and forest tracts. It therefore implies that the donees needed to develop their respective granted areas into cultivable plots. This paved the way for unprecedented expansion of agriculture into areas away from the 'areas of attraction'. The spread of agriculture is also reflected in the composition of a few treatises on the subject, notably the *Krishiparasara*. This text is believed to have been written in the middle of the eleventh century; the internal evidence of the text also indicates that its author was familiar with the condition in eastern India (more specifically Bihar and Bengal).[11] An analysis of certain words in the *Krishiparasara* by Lallanji Gopal conveys its association with eastern India and Bengal. The term for the goad in this text, for instance, is *paccani* which closely corresponds to *panchan-badi* in Bengali. Similarly, the term *madika* connotes a harrow and has a clear affinity with the Bengali word *moi*. Gopal also finds a strong similarity between *kattanam* (the technique of harvesting) and *kadan* in Bengali. These regional features apart, the text in question addresses the issues of the following agricultural processes: collection, preservation and sowing of seeds, levelling of the field after sowing, harvesting of ripened crops, separating the grain from the stalks, weighing them and the arranging their storage in the granary. Thus, this technical treatise on agriculture takes into account a wide range of aspects of cultivation: right from ploughing to harvesting and finally, to the storage of crops. The Puranic statement that in the Kali age (viewed as the worst of the four cyclical *yuga*s in traditional concept of time) agriculture turned out to be the common occupation for all people irrespective of their *varna-jati* rankings (*kaliyuge krsi khalu samanyavrtti*), may be appreciated in the context of the agrarian conditions

[10] Sircar, *Indian Epigraphy*, see the section on the 'Creation of Revenue–free Holdings'.

[11] Gopal, *The Economic Life of Northern India*, appendix II on 'Technique of Agriculture' (esp. pp. 294–313); Majumdar and Banerji, *Krishiparasara*, see the Introduction (esp. pp. xix–xxi).

of the early medieval period.[12] This has wide implications. First, as R.S. Sharma has pointed out, it probably recognises that the *sudra* could take up the profession of an agriculturist; this is in sharp contrast to the Vedic notion that serving the three upper *varna*s (*dvijatisusrusha*) had been the only prescribed and fitting function for the *sudra*.[13] It is distinctly likely that with the spread of agriculture into hitherto uncultivated tracts many tribal groups who became sedentary agriculturists were brought under the *sudra* category. While a major instrument of agrarian expansion was the issuance of copper plate charters, the main beneficiary of this institution was the priestly community. The brahmana who was normally not to take to agriculture would be allowed in some of the early medieval treatises to practise it. Thus the *Parasarasmriti* not only considers that agriculture was a conduct applicable to all four *varna*s, but also prescribes it for a brahmana who engaged in his sixfold duty (*shatkarmanirata*). *Brihat-Parasara* too finds that agriculture was a suitable vocation for brahmanas (*kartavyam karshanam dvijaih*). According to the same authority, agriculture superseded cattle-keeping (*pasuposhana*), trade (*kritavikrita*) and royal service (*rajasevana*).[14] The intention of the text is unmistakable: if agriculture was the best of the occupations then it should be available to the highest *varna*.

The agrarian expansion during the early medieval times has evoked diverse and contesting explanations among historians. The early middle age in Indian history is perceived as a period of transition from the ancient or classical phase to the medieval by some of them. According to the proponents of Indian feudalism, the rural expansion was both a cause and an effect of a decline in the erstwhile vibrant crafts and commercial economy on the one hand and the urban decay on a pan-Indian scale on the other. That is why rural expansion in the early medieval times is presented in this genre of historiography as a contrastive category to urban expansion. The rural expansion is assumed to have paved the way for a self-sufficient and enclosed village economy. The formulation has been contested both on empirical and conceptual grounds. Rural expansion in early medieval India, it has been argued, does not necessarily indicate the emergence and consolidation of undifferentiated and isolated rural units. There is no unanimity in the view that the spread of agriculture

[12] Chakravarti, *Prachin Bharater*.
[13] Sharma, *Early Medieval Indian Society*: 26, 34, 197–200.
[14] Texts cited in Gopal, *Aspects of Agriculture*, pp. 26–28.

was mutually incompatible with commercial networks and urban development. In fact, the urban centres of early medieval India and many of the locality level exchange centres are found to have been integrated to their adjacent rural hinterlands. This process of 'local formation' and development from within is considered to be the hallmark of what has been labelled as the 'third urbanization' in India.[15]

These preliminaries help us better situate the development of paddy cultivation over greater parts of north India. While the *Sunyapurana* enlists as many as 60 varieties of paddy in eastern India,[16] even a relatively arid region like Rajasthan experienced the generation of both summer (*graishmaka*) and autumn (*saradiya*) crops, which included not only wheat and millet, but rice too.[17] Paddy cultivation seems to have been facilitated by the spread of the technique of transplantation of seedlings. This point is emphasised by the *Krishiparasara*. It is generally believed that transplantation of seedlings led to greater output of paddy. The spread of agriculture was instrumental in the cultivation of a few non-cereal crops which were indispensable for a few agro-based crafts and artisanal activities. Of such 'cash crops', the foremost must have been the cultivation of cotton which provided the raw material for the vibrant textile production in India, celebrated over centuries. The study of textile production and textile technology has a special niche in the history of Indian crafts and technology, and it has in fact emerged as a distinct subdiscipline.[18] Attention must be paid to the cultivation of sugarcane, the best variety being grown in Pundravardhana (north Bengal). From the days of Banabhatta, the famous author of the *Harshacharita*, to the Arabic and Persian writers on travel and geography (eleventh–thirteenth centuries), the sugarcane of north Bengal received sustained praise. Sanskrit treatises labelled it as *paundraka,* literally something associated with or coming from Pundra. In this context one comes across the mention of a device for crushing sugarcane (*ikshupidanayanatra*), obviously for the purpose of extracting the juice which would be used to manufacture sugar and other by-products. The use of this device became so common that the twelfth-century lexicon, *Desinamamala* of Hemachandra, explained

[15] See further discussions in the later part of this article.

[16] Yadava, *Society and Culture*: 258, 309; fn. 93.

[17] Chattopadhyaya, *Early Medieval India*, especially the chapter 'Irrigation in Early Medieval Rajasthan'.

[18] See, for example, Ramaswami, *Textiles and Weavers*.

it as *hastayantra*, implying that the device was hand-operated. The availability of such devices may explain the spurt of the sugar-making industry in Rajasthan and Malwa in early medieval times. The sugar of the latter area in fact reached the ports of Gujarat for overseas export, as Chau ju Kua reports it in 1225.[19] Another agro-based craft, inseparably associated with daily life, was that of edible oil production. The primary raw material undoubtedly came from oil seeds. The proliferation of the oil-miller's craft is amply borne out by regular references to *tailika*s or *telika*s (oilmen) in both epigraphic and literary sources. The *Jayamangala*, the tenth-century commentary on Vatsyayana's *Kamasutra*, informs us about two devices for oil pressing. The first was *audra*, which was used as an oil press. The other device was known as *chakrika*; the term is suggestive of its circular wheel-like shape (*chakra*) and/or its circular rotary motion. There is a distinct possibility that the *chakra* or oil-pressing wheel had a horizontal rotary motion. The *Jayamangala* leaves us with an impression that it rotated on all four sides or directions (*chakrika tu chatursu parsveshu chalyamana*). Textual and epigraphic sources further offer another synonym of the oil-pressing device with a circular motion: this is *ghanaka*, surviving in the modern term, *ghani*. It is not uncommon to come across references to the gift of *ghanaka*s to temples at the time of the land grant in early medieval inscriptions. This was probably done with a view to supplying oil to the sacred centre both for burning lamps and also for cooking of food for the residents in a religious complex. Significantly enough, in an inscription dating 1034 from north Konkan, a person who would cause damage to the *ghanaka* is threatened with dire consequences in this world and the next. Such imprecatory verses as these in land grants are significant markers of the importance of oil-pressing devices in the material life of early medieval India.[20]

Gopal points to the possibility of the improved understanding of manuring the field for success in crop production. Though manuring has been discussed in pre-A.D. 500 texts, the subject received more sustained attention in technical treatises of the post-A.D. 500 days. The significance

[19] Gopal, *Chau ju Kua*, Chu fan chi (translated by Hirth and Rockhill): 111; also see Jain, *Trade and Traders*: 58–59, 103–4.

[20] Chakravarti, *Prachin Bharater*: 199–200; also see Chakravarti (ed.), *Trade in Early India*, especially the chapter by the editor titled 'Monarchs, Merchants and Matha in North Konkan (900–1053)'.

of manuring is clearly recognised in the *Vrikshayurveda* (lit. the science of plant life). The *Brihatsamhita* of Varahamihira has a section on *Vrikshayurveda* which recommends the following preparation of manure:

> To promote inflorescence and fructification, a mixture of one *adhaka* (64 *palas*) of sesame, 2 *adhakas* of excreta of goats or sheep, one *prastha* (16 *palas*) of barley powder, one *tula* (100 *palas*) of beef thrown into one *drona* (256 *palas*) of water and standing over seven nights should be poured round the roots of the plant.

The text also recommends the sprinkling of the washing of fish for the preparation of manure. Similar chapters on *Vrikshayurveda* figure in the *Vishnudharmottarapurana* and the *Agni Purana*. Both the texts uphold the mixture of powdered barley, sesame and the offal matter of goat, soaked in washings of beef and fish for seven consecutive nights. The encyclopaedic *Manasollasa* of King Somesvara II (1126–38) advises the digging of a pit measuring four *hasta*s (cubit) in depth and diameter alike, which is to be filled with bones and cow dung. These are then to be burnt and the ashes to be later removed. This should be followed by filling the pit with sand and the washing of a she-goat's fat sprinkled over it.

Most authors of the *Vrikshayurveda* have naturally paid maximum attention to the use of cow dung in their discussions on manure. Though the use of cow dung as fuel may go as far back as in the Atharvaveda, Gopal finds the first clear use of the cow dung as manure in the *Harshacharita* of Banabhatta (seventh century). Bana graphically describes how a peasant carried cow dung (*karisha*) along with other rubbish in ox-driven carts (*sakatasreni*) to a field for the purpose of increasing the weakened fertility of the plot (*sampadyamanadurbalorvirukshakshetrasamskaram*). A more systematic account is available in the following extract from the *Krishiparasara*.

> In the month of Magha (January–February) a dung heap (*gomayakuta*) is raised with the help of spade (*kuddala*). When it is dried in the sun (*raudre samsoshya*), smaller balls are made out of it (*gundakarupinam*). In the month of Phalguna (February–March), these dried balls of dung are placed into holes dug for the purpose in the field (*saram garte nidhapayet*), and at the time of sowing (*vapanakale*) they are scattered over the field (*saravimochanam*).

The merits of this method are that the undisturbed dung heap minimised the loss of nitrogen, the chief fertilising element; that the drying of the dung into balls reduced ammonia which is injurious to plants; that the dung balls in the pits augmented humus, thereby further fertilising the soil.[21]

It is no wonder that of all agricultural technologies maximum focus falls on the adequate usage of the hydraulic endowments. The expansion of agriculture, the diversity and profusion of crops—both edible and non-edible—and the growth of a complex sedentary society were further related to the availability of sufficient irrigation facilities. While India's material culture is rooted in agriculture, the agrarian sector of the economy, in turn, is inseparably linked with irrigation devices and technology. Although the monsoon regime has been immensely beneficial for Indian agriculture over millennia, the vagaries of monsoon can drive peasants and polities from prosperity to abject poverty. Diverse devices and technologies to nurture and utilise the precious hydraulic endowments have therefore been a sustained and engaging concern in India over protracted periods.

The profusion and diversity of agricultural crops in India indicates the awareness among Indians from remote Antiquity about climate and its interaction with soil and water. They accorded importance to the variations in rainfall patterns in different regions of the vast subcontinent, where the success or failure of agriculture is largely dependent on the distribution of rains borne on the monsoon winds—the principal share of rainfall from the south-west monsoon from June to September, and the north-east monsoon affecting peninsular India from October to February.

Though the traditional Indian scheme divides the year into six seasons, each consisting of two months (possibly attempting an impression of neat symmetry), there is also an alternative system of dividing the twelve months into three dominant seasons, each spanning over four months: namely, summer (*grishma*), monsoon (*varsha*), and winter (*hemanta/sita*). The latter tripartite division is mainly encountered in inscriptions

[21] This section on manure draws largely on Gopal, *Aspects of Agriculture.* The chemical properties of cow dung were suggested by R.Gangopadhyay, cited by Gopal. Furui, 'The Rural World of An Agricultural Text' presents a fine study of the agriculturists and their practices on the basis of this text.

of the late centuries B.C. and early centuries A.D. This scheme clearly highlights the importance of the heavy rains brought by the south-west monsoon, the reality of which is experienced in India for nearly four months (June–September). These rains, however, are unevenly distributed and also uncertain and can enhance or doom agrarian production on account of excessive or meagre rainfall. This uncertainty of the monsoon rains paves the way for the insistence on irrigation systems which could provide support to the cultivator especially during lean seasons. The storage and distribution of water is a precondition everywhere for the growth and spread of agricultural settlements.[22] It is significant to note that an early medieval text, *Brihatkalpasutrabhashya*, shows a remarkable awareness of the variability of hydraulic endowments and therefore the diversity of storage systems and irrigation mechanisms in disparate regions of the subcontinent. The text in question tells us of the dependence of Lata (southern Gujarat) entirely on rain, of Sindhu (lower Indus valley and the Indus delta) on rivers, of the Dravida country (far south India) on reservoirs, and of Uttarapatha (generally north India, but also denoting in a restricted sense the area in present Haryana and Punjab) on wells.[23] The above statement is to be understood in the context of various irrigation practices in different regions of India which certainly experienced considerable variation in precipitation. The *Krishiparasara*, in the first section, devotes considerable attention to the interrelation between rainfall and agriculture. The author of this text recommends the ascertainment of the amount of rainfall with the help of a rain gauge.

The most striking feature of the climate of South Asia is the more or less predictable alteration of the monsoon winds which bring in profuse rains to the region, especially to India, Sri Lanka, and Bangladesh. This particular natural phenomenon continues to engage the attention of geographers and climatologists and had captured the attention of early writers too. As early as the fourth and third century B.C., Megasthenes noted in his *Indika* that the agrarian prosperity of India was largely due to two

[22] Spate and Learmonth, *India and Pakistan.* Traditional Indian understanding of seasons led to the formulation of *rituvijnana* which L. Gopal considers to be 'climatology' that 'developed along with astronomy' (Gopal, 'Agriculture').

[23] Cited by Gopal, 'Agriculture': esp. 421; also see, Chakravarti, 'Natural Resources and Human Settlements': 48–65.

rainy seasons, facilitating the generation of a double crop.[24] The eleventh-century author of medical treatises, Chakrapanidatta, was not only aware of the monsoons, but presents a twofold division of the rainy season. This consisted of the season of the outburst of rain (*pravrish*) and profuse rainfall (*varsha*). His perceptions about the twin divisions of the monsoons, by which he understood the south-western monsoon system, are rooted in the southern part of the Ganga basin.[25] The understanding about the rainfall patterns in India in the eleventh century did not escape the notice of the erudite observer al-Biruni in the early eleventh century. 'India has the tropical rains in summer, which is called *varshakala*', he wrote, 'and these rains are more copious and last the longer the more northward the situation of a province in India is and less it is intersected by mountains'.[26]

A few more words on the monsoons and their bearing on the possible rainfall pattern in the eleventh century may be in order at this juncture. The historian is particularly indebted here to the studies of earth scientists for their unravelling of the long-range history of the monsoons. The monsoon wind system affects not only the climate of the Indian subcontinent, but also that of North-east Africa and the coastal areas of East Africa.[27] Earth scientists observe that the almost clockwork precision of the monsoon has a close relationship with the seasonal cycle of the sun's track across the sky. Yet there can be considerable variation in the patterns of precipitation during a certain period, bringing in phases of relative lack or profusion of rainfall in wide areas of Eastern Africa and South Asia. In other words, geographers underline that the pattern of precipitation in South Asia cannot be studied in isolation, but should be linked up with the situation in Eastern Africa.

The monsoon fluctuations over large and disparate areas of Africa and South Asia show a striking affinity. This results in the onset of droughts

[24] Majumdar, *The Classical Accounts of India*: 252.

[25] F. Zimmermann, 'Monsoon in Traditional Culture'. It is significant that Ibn Majid, the greatest navigator in the western Indian Ocean in the fifteenth century, was fully aware of the fury of the sea, swelled by the typical summer monsoons, and recommended voyages across the western Indian Ocean only with the gradual slackening of the south-western monsoon after late August. He termed the rainy season as *vishkal*, obviously derived from the Sanskrit term *varshakala*. See Tibbett, *Arab Navigation*.

[26] Sacahu, *Kitab al-Hind*: ch. XVIII, vol. I, pp. 211–12.

[27] Fein and Stephens, *Monsoons*. Also see Diaz and Markgraf, *El Nino.*

in both Africa and South Asia at certain common timeframes and demonstrates that the African monsoon's decade-scale fluctuations share certain similarities with the changes of rainfall on the Indian subcontinent.[28] While the variability of the rainfall patterns in the Indian context is available only from the 1840s onwards—thanks to the pioneering efforts of Gilbert Walker in the preparation of rain gauge records—historical evidence of the annual rhythm of the monsoon from a much remoter Antiquity is available in the Nile river system. Omar Tousson, by his meticulous study of the Nile river flood data, pushed back the evidence of keeping rainfall records to A.D. 622.[29] Since that date, till recent times, the highest and the lowest levels of the Nile flood were measured every year with the help of a gauge called the Nilometer, located at Roda Islands near Cairo.

A high level of the Nile flood has close correspondence with the regular and heavy monsoonal rains in East Africa and on the Indian subcontinent. A low Nile flood is an indicator of a weak monsoon regime for a particular year or period. Gilbert Walker used the Nile floodwater data of 1300 years (622–1925) to infer possible variability of the Indian monsoons. He noted the 'tolerably close correspondence between the abundance of the Nile floods and that of the monsoon rains of Northwestern India'. The *Imperial Gazetteer of India* (vol. 1) stated that,

> [I]t is now fully established that years of drought in Western or Northwestern India are almost invariably years of low Nile flood. The relation is further confirmed by the fact that years of heavier rain than usual in Western India are also years of high Nile flood.[30]

No less significant is the observation of the geographers that the years of low Nile flood correspond to cooler periods in Western Europe where long-range meteorological data have been more precisely recorded. The chief significance of this exercise of looking into the rainfall pattern in the Nile catchment area and the cool and warm phases in Western Europe lies in the fact that these have distinct bearings on the rainfall pattern in the Indian subcontinent.

[28] Kutzbach, 'The Changing Pulse of the Monsoon'; Quinn (1992), 'A Study of Southern Oscillation'.

[29] Toussoon, *Memoire sur L'Historie du Nil*.

[30] Quoted in Quinn (1992), 'A Study of Southern Oscillation': 125.

Tousson's presentation of the Nile flood data from 622 to 1522 offers important insights into the possible rainfall patterns in the Indian subcontinent. The 378 years that elapsed between A.D. 622 and A.D. 999 witnessed 105 years of weak Nile flood (27.8 per cent weak flood years). This implies a corresponding low rainfall during those years in the Indian subcontinent and a cool period in Western Europe. Only 23 years of low Nile flood are noticeable in the rainfall computations for the 290 years from A.D. 1000 to A.D. 1290 (8 per cent weak flood years). During the subsequent period of 231 years (A.D. 1291–1522), the total years of low Nile flood amounted to 50 years (21.60 per cent weak flood years). The least percentage of weak Nile flood therefore is seen in the first three centuries of the second millennium.[31] The possible years of weak Nile flood and hence low monsoon rains in the subcontinent during the eleventh century, according to the table prepared by Quinn,[32] were 1007, 1008, 1023, 1036, 1037, 1057, 1066, 1072, 1085, and 1096: a total of 10 years of low monsoon rains in India during the eleventh century. One may thus cogently argue that the onset of the eleventh century brought about greater amount of rain in India than the preceding two or three centuries. It would therefore not be unlikely to logically assume that during the eleventh century the climate in the subcontinent was more moist than during the previous century, and this could have considerably enhanced the hydraulic resources in this century compared to the previous ones.[33]

[31] *Ibid.*: 143, demonstrates that the period 1000–1290 represented the Little Climatic Optimum (LCO) and the subsequent 1291–1522 phase was an interim period between the LCO and the Little Ice Age (LIA), and 1694–1899 was located in the LIA. See particularly the Table 6.7 in Quinn (1992).

[32] *Ibid.*: 140–1.

[33] Utilising the Nile flood data, M.K. Dhavalikar speaks of a long period of relative lack of rain and consequent aridity in India from the seventh century onwards. This, in his opinion, very adversely affected human settlements in India during the post-Gupta times (c. A.D. 600–1200). Dhavalikar draws from various literary sources to suggest an environmental change during this time leading to frequent outbreaks of famine. He argues that the lack of monsoonal rain and relative aridity contributed to the decline of many flourishing urban centres of pre-A.D. 600. He thus highlights the environmental factor in the urban decay of India during the post-Gupta times. See Dhavalikar, 'The Golden Age and After'. While his suggestions of a long period of relative aridity in India after A.D. 600 are apparently supported by the Nile flood data and the data on increasing cold climate in Western Europe, it is difficult to subscribe to his thesis of wholesale and widespread decay of urban centres in India after A.D. 600. He obviously bases himself on the concept of 'urban anaemia' propounded by Sharma, *Urban Decay in India*. The validity of the perspective

Such an environmental scenario could have been conducive to the spread of agrarian settlements in India in the eleventh century. The early medieval period in Indian history, and especially the period since 1000, looms large in the economic historiography of early India as one of unprecedented rural expansion which would have been barely sustainable without adequate hydraulic resources.

These observations pave the way for our discussion of the early Indian understanding of human habitations. In most literary presentations, the forest (*aranya*) was conceived of as an arena for wild beasts, dangerous robber and fierce demons (*rakshasa*) defiling the sacred sacrifices of sages and forest hermits who had their hermitages (*asrama*) there. The forest was thus perceived as a space in contrast to the settled environment of the village.[34] Sanskrit sources described a settlement area with multiple villages as a territory (*rashtra*) or a *janapada*, referring to the feet (*pada*) of the people (*jana*): in other words, the term *janapada* conveys the sense of an area where a given people first set foot, that is settled down. More specifically, these terms distinguished agricultural settlement spaces from both city (*pura/nagara*) and fortified capital (*durga*). The ideal *janapada* would naturally have arable tracts (*kshetra*), habitation areas (*vastu*) and uncultivated land (*khila*).[35] The space intervening between the *janapada* and the forest was generally earmarked as pasture grounds (*vraja/gochara*).[36] The spread of sedentary agricultural settlements from around 1000 involved changes in virgin, pasture and forest tracts.

Insightful analyses of the copper plate charters during the last decade effectively demonstrate that rural settlements were neither undifferentiated nor isolated, thereby sharply critiquing the well entrenched notion

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of an overall urban decline in the entire subcontinent has been questioned on both empirical and conceptual grounds. See Chattopadhyaya, *Early Medieval India* and 'State and Economy in North India'. See also Champakalakshmi, 'State and Economy in South India' and *Trade, Ideology and Urbanization*. A recent critique of the concepts of declining trade and urban contraction is available in Chakravarti, *Trade in Early India* and 'Review of D.N. Jha'.

[34] Malamoud, *Cooking the World.*

[35] Rural settlements figure in royal charters with high and low lands (*satala-soddesa*), saline areas with pits (*sagarttosara*), dry and wet tracts (*sajalasthala*), shrubs and bushes (*sajhatavitapa*), dumping grounds (*avaskara*) and grasslands for grazing of cattle extending to the end of the village (*sasimatrinaputigocharaparyanta*).

[36] Chakravarti, 'The Creation and Expansion of Settlements': 87–105.

of the self-sufficient, stagnant and enclosed village in traditional India. We therefore need a model of agricultural expansion that describes activities taking place in multiple villages. We cannot evaluate settlement expansion and the enhanced use of natural resources, including hydraulic reserves, merely according to the *Arthasastra* model dating back to the third century B.C., which recommended an active and predominant role of the political authority in the creation of fresh *janapada*s.[37] The *Arthasastra* measures are often portrayed by historians as a uniform and standard method for creating new settlements irrespective of time and space, through intense involvement of royal administration. It is suggested here instead that the clue to settlement expansion lies in the creation of revenue-free land grants largely in favour of religious donees.

A closer investigation of regional traditions of water management might be elusive. At first the agricultural and hydraulic situation of the Northeast is to be investigated. One inscription from Bangladesh portrays the largest known Brahmanical colonisation programme in north India, planned and designed by a political authority: an extensive settlement created in the tenth century in Srihatta (Sylhet area). The impressive size of the settlement, probably created out of virgin tracts (*bhumicchidranyayena*), is evident from the considerable administrative restructuring required to assemble a contiguous tract, involving the merging of three districts (*vishaya*). This area had extensive forest and marshy lands in descriptions on copper plates from seventh and eighth centuries. In 930, it became a *brahmapura* with 6,000 *brahmana*s and their families, a large number of craftsmen and service groups. The record informs us of the presence of outsiders (*desantariya*) in Srihatta and of people from Vangala (*vangaladesiya* [Vangala = Barishal, Bakarganj area in Bangladesh]), indicating the populating of this area with inhabitants brought from elsewhere.[38] Though the immigrants propitiated identical deities (Mahakala, Jaimini, Yogesvara and Agni), they required two separate monastic establishments; this is a unique event in early medieval

[37] See the treatment of *janapada* creation (*janapadanivesa*) in Kautilya, *Arthasastra*: vol. 2, chapter 1.

[38] One may assume that the sharp difference between the *desantariya* and the *vangaladesiya* in the newly created 'brahmana city' could signal their unequal access to resources in this area. See Ray et al., *A Sourcebook of Indian Civilization*: 634–35.

Indian history.[39] This entire complex was certainly sustained by agricultural resources obtained by bringing hitherto uncultivated tracts under the plough.

An interesting variation is visible in the Varendri region, the very heartland of the Pala dynasty (ca. 750–1200). Varendri (corresponding to Rajshahi, Bogra, and Dinajpur areas in modern Bangladesh) had been a flourishing, settled area for centuries, and stood as the ancestral home of the Pala kings.[40] They temporarily lost control of it because of an internal rebellion in about 1070. Royal control was restored under Ramapala (1072–1127), the last great ruler of the dynasty and the hero of the celebrated Sanskrit text, the *Ramacharitam* of Sandhyakaranandin. After narrating how the Palas re-established political authority in Varendri through supplanting the rebel, the text describes the attempts undertaken to improve the war-ravaged agrarian economy. Besides bringing back regular cultivation, Ramapala is credited with the construction of 'public works of great utility in the shape of large lakes with tall palm trees and lines of hillocks on their border, so as to make them look like veritable seas'. These artificial water bodies were certainly larger and more impressive than ordinary tanks (*tadaga*) and ponds (*pushkarini*) and represent an amplification of hydraulic resources. No less significant is the text's account of the levy of only mild taxes, obviously to ensure that the local human resources did not desert the war-torn territory.

The greater part of the Ganga River valley and the Ganga delta was watered by perennial rivers of glacial origin and well nourished by rains. This region, including Bengal, belonged to the category of *devamatrika* (area with profuse rainfall) and *nadimatrika* (riverine) tracts. Within this environment, hydraulic resources and facilities were important landmarks of rural space. The eleventh-century charters from Bengal and

[39] Sircar, *Select Inscriptions*: 92–94.

[40] Northern Bengal had a complex and developed economy with a strong agricultural foundation as early as the third century B.C., as illustrated by the fragmentary Mahasthangarh stone plaque inscription. This record mentions the cultivation of paddy and sesamum, a royal granary and the well-planned, prosperous city of Pundranagara (Mahasthan in Bangladesh), the earliest known urban centre of Bengal and still an impressive archaeological site. The region's prosperity continued in the Gupta age (fourth to sixth centuries) and during the reign of Sasanka (c. A.D. 600 to A.D. 619 if not up to A.D. 637). Varendra or Varendri, in the heartland of north Bengal, was described as the ancestral home (*janakabhu)* of the Pala kings in the *Ramacaritam*. See Shastri (ed.) and Basak (revised), *Ramacaritam*: I.48, II.28 and V.3.

Bihar contain regular references to rivers, streams (*srotosvini*), rivulets (*ganginika*), dikes (*khata/kulya*) and embankments (*ali/brihadali*). Aside from the panegyric of Ramapala's interventions, there is little indication of the construction of large, supra-local hydraulic projects by politico-administrative authorities in this region.[41]

We may now turn our attention to the more arid western India, especially Rajasthan and Gujarat, the latter becoming more famous for its agrarian economy featuring cereals and cash crops like cotton, oilseeds, indigo and sugar cane. Agricultural prosperity is evident from indigenous sources and also from prominent references in Arabic, Persian and Chinese accounts. One source describes the transformation of an uncultivated highland (*uddhakhilabhumi*) into an arable tract by a farmer who is said to have newly arrived from outside (*navyasamayatakutumbikaih*).[42] Hemachandra (1088–1172), the famous Jaina writer from Gujarat, seems to have been aware of the effects of growth on agrarian settlements when he suggested, in his *Parisishtaparvan*, that many villages were beginning to assume the character of towns (*gramascha purasannibha; Parisishtaparvan* I.8).[43] The agrarian growth was certainly due in part to

[41] The only exception to this general pattern is the unique practice of levying a water cess (*jalakara*) in the twelfth-century Gahadhavala realm around Kanyakubja. See Sircar, *Indian Epigraphical Glossary*: 132.

[42] Indian texts and copper plate charters seem to differentiate a hitherto uncultivated tract (*khila*) from an arable plot deliberately left or kept fallow (*khilakshetra*). It is a common and traditional agrarian practice that arable plots were occasionally kept fallow for a period to restore their fertility. In a thirteenth century copper plate from south-eastern Bangladesh, administrative abbreviations were used to suggest such different categories of fallow tracts. Thus *mu-ti* (*mundatikkara*) meant a tract kept fallow while *chi-khi-mu-ti* (*chirakhilamundatikkara*) stood for a tract never before brought under the plough. See *ibid*., s.v.

[43] This description provides a counterpoint to the account of towns in the *Brihannaradiya Purana*, where towns were beginning to wear the look of villages (*nayarani gamabhuyani hohinti*), used by Yadava, *Society and Culture*:141, to impress upon urban decay and ruralisation in the wake of a decline in trade and crafts. Contrary evidence that agrarian prosperity and expansion of agriculture could turn a village into a node for local–level grain exchange comes from an epigraphic reference to Naddula, a village in Rajasthan. See Chattopadhyaya, *Early Medieval India*: 98 and Ranabir Chakravarti, *Trade and Traders* (chapter on the Mandapika). Located in close proximity to 12 villages, it gradually became a local level market centre (*mandapika*), then a city (*nagara*), and finally the political seat of the Nadole Chahamana kings. Chattopadhyaya, *Rural Settlements and Rural Society*,

improved iron technology, for Hemachandra was aware of the regular use of iron implements for agriculture. No less instrumental was the introduction of technology to utilise hydraulic resources for transforming undeveloped (*akrita*) into developed (*krita*) agricultural tracts.

Reservoirs were used for irrigation (*sechanartham*) and for moistening sown seeds (*siktam bijam*), as mentioned in the Jaina text *Upamitibhavapr apanchakatha* (906). Besides the usual local level irrigation projects like tanks and wells (*kupa*), new irrigation tools like *araghatta/arahatta* and *vapi,* particularly suitable for lifting water from great depths, began to appear in texts describing technology. While the *araghatta* is a type of water wheel in wide use,[44] the *vapi* (a term derived from the Sanskrit root *vap*, meaning to sow) describes the step-wells (*baolis*), which abound in Gujarat even now. The device *araghatta* demands close scrutiny. The *Gathasaptasati* of Hala (c. early centuries A.D.) gives one of the earliest accounts of the device under the name *rahattagadiya* (Sanskrit: *araghattaghatika*), or a wheel fitted with buckets. That the earliest epigraphic mention of the device goes back to A.D. 532 in the Mandasore *prasasti* of Yasodharman was convincingly demonstrated by M.C. Joshi.[45] The inscription presents a poetic account of a fine well (*satkupa*), which is expected to be as perpetual as the ocean and the moon. The said well had the elevational grace (that is charming skyline) of a mansion

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has illuminated the history of a village named Kalikatti in twelfth-century Karnataka, which began as an ordinary village, then became an outstanding or most prosperous village, then assumed a nearly urban profile.

[44] The term *araghatta* is also explained in lexicons as a deep well. The term is occasionally mentioned along with another irrigation device, called *ghatiyantra* or a pot garland. Such a device consisted of a number of pots tied to a rope, probably set on a deep well and moved with the help of a pulley. The *araghatta* and the *ghatiyantra* were particularly useful in dry and arid regions where groundwater could be reached only at a considerable depth.

[45] The inscription is available in Fleet, *Corpus Inscriptionum Indicarum*, III, see especially verse 27; M.C. Joshi, 'An Early Inscriptional Reference': 217. The present author however does not consider this device a Persian wheel. The use of the *araghatta/ghatiyantra* became so common that this was used as a metaphor in ornate Sanskrit court poetry. Thus in the *Vikramankadevacharita* Bilhana compared the excellence of Chandralekha's necklace with that of the water wheel (*ghatiyantragunopamah*). He compared big pearls of the necklace to the pots attached to the rim of the wheel: as if these were drawing the drink of loveliness from the navel (*nabhilavanyapaniya*). The *ghatiyantra* thus is endowed with considerable sensuousness in this image.

(*saudhanta*); was notable for its 'rotary motion (*valayaparigati*), resembling a garland of skulls (*mundamalamivayam*)', and discharged nectar-like pure water (*amritasamarasasvachchhavishyanditambu*).

An essential part of the *araghatta* was the *ghatiyantra* or the device with pitchers, usually mounted on the wheel, but not attached to its rim. The *ghatiyantra* as an irrigation device is therefore often held as a 'pot-garland'. The *Upamitabhavaprapanchakatha* of Siddharshi (906) presents the most elaborate account of the device. The water available through the *araghatta* irrigated (*sikta*) the seeds which would blossom into luxuriant crops. The *araghatta*, according to the text, seems to have drawn water from a reservoir which in its turn received its water from an irrigation (*sechanartham*) well. So deep was this well that its bottom was invisible. The text unmistakably highlights its two salient features: the spokes (*araka*s) of the wheel which was a revolving apparatus (*satatabhrama*).[46] This water wheel however did not have the pots/pitchers attached to its rim, but the chain of pots was instead mounted on the wheel which was quite clearly separate from the pot-garland. The text does not refer to any gearing mechanism enabling the conversion of the horizontal rotary motion into a vertical rotary motion. The latter feature became visible from the fourteenth century onwards and, as has rightly been suggested by Irfan Habib, represented the typical Persian wheel or the *saqia.*[47] The

[46] Gopal, Agriculture: 427–28.

[47] Habib, 'Presidential Address'. The term *araghatta* is often translated as Persian wheel. Irfan Habib however is of the opinion that the Persian wheel (*saqia*) was not in regular use in the Indian agrarian scenario prior to thirteenth–fourteenth centuries when it reached India in the aftermath of the Turkish conquest. He differentiates it from *noria*, that is a water wheel carrying pots or buckets fixed on its rim. The *noria*, prevalent from the nine–tenth centuries onwards, however, did not have a chain to carry pots nor did it have a gearing mechanism, typical of the *saqia*. Irfan Habib proposes a two-stage development of the water wheel from the *noria* to the *saqia*. Harbans Mukhia suggests, on the other hand, a three-stage development of the same, situating the *ghatiyantra* of Sanskrit sources. The *ghatiyantra* was an improvement, according to him, upon the *araghatta* as it had the bucket chain, but the gearing mechanism—so typical of the *saqia*—had not yet arrived. This has led him to perceive a three-stage development of the water wheel in India. See Mukhia, 'Agricultural Technology': 228–29, 240–41. However, as early as the third century, the *Gathasaptasati* of Hala spoke of *rahattagadiya*, that is *araghattaghatika*. The term may refer to a water wheel fitted with buckets, although the existence of any chain mechanism is not hinted at. Could it possibly point to a mechanism that was in between the usual *araghatta* and the later *ghatiyantra*? It is therefore better to employ the term *araghatta*

prevalence of *araghatta* as a hydraulic machine is best demonstrated by an eleventh-century panel from Mandor (Pali district, Rajasthan). From the left to the right, the panel presents a group of warriors, the waterwheel with pots (*araghatta*), the operator of the device and an animal. The six spokes of the wheel are clearly visible and there were possibly other spokes too which are concealed. The pots with pronounced and flaring mouth are mounted on the outer rim of wheel with ropes at regular intervals. The position of the wheel and the direction of the pots unmistakably indicate the rotary motion of the wheel, and that too in the anti-clockwise direction.[48]

Now to the term *vapi* standing for another type of irrigation work which began to figure prominently since the early medieval times. It is derived from the root *vap* (to sow); therefore its close association with irrigating the cultivated tract goes beyond any doubt. It has wide distribution in the arid regions of Gujarat and Rajasthan and is the same as *baoli* of modern times. Its importance as a step-well to reach the groundwater at considerable depth can hardly be overestimated. In sharp contrast to the stray references to the *vapi* in the tenth-century *Samaranganasutradhara* of Bhoja, the *Aparajitaprccha* of Bhuvanadeva devotes a full and elaborate chapter to local level irrigation devices including the *vapi*.[49]

The security provided by a branch of the Chalukyas in Gujarat as dominant regional rulers encouraged the tendency to build storage tanks and other irrigation projects. Thus, Mularaja (941–996) is known to have directed his officers to dig wells and tanks and construct *vapi*s. The tank excavated at Anahilapataka (present day Patan) was named after Durlabharaja (r. 1010–24). Similarly, the two tanks commissioned under

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in the generic sense of a water wheel and not as the subsequent and technologically much more advanced Persian wheel. That *araghatta*s were widely used as a hydraulic mechanism will be evident from its use as a simile in Jaina literature. Merutunga, author of the *Prabandhachintamani*, compares the fickleness of fortune with the circular rotation of buckets on the water wheel (*ghatijalayantra chakre*) (quoted in Jain, *Trade and Trader*s: 29).

[48] The sculptured panel was first noticed by Agrawala, 'Persian Wheel in a Rajasthani Sculpture': 87–88; a photograph of it is available in 'India at Work', published by the Centre of Advanced Study, Department of History, Aligarh Muslim University, on the occasion of the Indian History Congress, 1994. The quotation used here is from Srinivasan, 'Irrigation and Irrigation Works': 587.

[49] Mankad, *Aparajitaprccha of Bhuvanadeva*, chapter LXXIV.

King Karna (1066–94) were named after him (Karnasagara); the same ruler is credited with the construction of a *vapi* at Davad. In 1099, the Chalukya king Siddharaja endowed a piece of land for the maintenance of a step-well that had been constructed by the son of a minister (*amatya*) in northern Gujarat. In some instances, the kings seem to have been directly involved in the construction of irrigation facilities; in most cases, they interacted with subordinates who took the initiative in consultation with local leaders.[50]

In Rajasthan, an area with less rainfall than Gujarat, inscriptions from the eleventh century suggest that the introduction of irrigation technologies resulted in the production of diverse crops even in this arid environment. *Vapi*s and *araghatta*s appear more frequently as important landmarks in the rural space in Rajasthani inscriptions of the eleventh century than in those of the ninth and tenth centuries. A sculpture from Mandore (c. A.D. 1200) depicts a scene of a water wheel and assembled men and beasts (including camels) flanking the water wheel on both the left and right sides. In 1059, another *araghatta* was constructed with reference to a rice field. Even more interesting information is furnished by an inscription of 1110 from Sevadi, Pali district, recording the connection of an *araghatta* with a double-cropped field yielding both summer and winter crops, described as *saradiyagraismakakshetra*.[51] There is little doubt that the introduction of the *araghatta* and the *vapi* considerably benefited agricultural production, especially because these were mostly in use in the relatively arid western India. But the new devices are unlikely to have been easily affordable for the common peasants. It is only the rich peasants and landlords who had adequate means and resources to invest in these new hydraulic technologies and devices. One recalls that in eighth century, Bodhgaya (in Bihar, under the rule of the Pala king, Dharmapala), the cost of excavating a tank and designing four divine images in a temple near that tank was 3000 *dramma*s (silver coins).[52] Whether the state authority directly invested in the development of these new technologies, and the extent to which they did, is difficult to determine. But these were indeed far outnumbered by the ubiquitous unpaved

[50] Jain, *Trade and Traders*: 24–34.

[51] Chattopadhyaya, *Rural Settlements and Rural Society*: 73–74 and *Early Medieval India*: 47, 49.

[52] The Bodhgaya Inscription of the Time of Dharmapala, regnal year 26, was edited by N. Chakrabarti, *Journal of the Asiatic Society of Bengal*: 101.

(*kachcha*) wells which ordinary and poor peasants could afford and had access to.

As we have already stated, the administration's role in water management is generally visible in the case of large-scale supra-local irrigation projects, often based on rivers. The most outstanding example of this comes from ninth-century Kashmir. Immortalised by Kalhana who in his *Rajatarangini* (twelfth century) wrote about the past of Kashmir with remarkable accuracy, the text graphically describes the vagaries of the river Vitasta (modern Jhelum) annually flooding the valley. During the reign of Avantivarman (c. 836–55), Suyya, who had mastered hydraulic technology, took measures to put a stop to the flooding of the Vitasta. There was a conscious attempt to divert the course of the Vitasta and to deepen the riverbed by desilting it. Suyya regulated the Vitasta by constructing several irrigation channels. Kalhana narrates:

> After examining the different classes of land he (Suyya) procured a supply of water for the villages, which were thus no longer dependent only on rainfall. After watering all the village (lands), he took from (each) village (some) soil, ascertained by observing the time it took to dry up, the period within which irrigation would be required (for each soil) respectively. He (then) arranged (accordingly) on a permanent basis for the size and distribution of the water course for each village and by (using for irrigation) the Anula and other streams, embellished all regions with an abundance of irrigated fields.[53]

Kalhana eloquently praised these efforts as a result of which the devastating annual flood of the river Vitasta was prevented. Not only was luxurious harvest achieved, but the price of paddy, now growing manifold, also came down.

We may now pass on to peninsular India, an area that may not be as arid as Rajasthan, but comes with its own uncertainties of rainfall and the resultant need to conserve hydraulic resources. The south-western monsoon brings in profuse orographic rainfall on the Western Ghat mountain ranges, but as winds pass on to the interiors of Maharashtra and Karnataka (popularly known as the *desh* area) they drop much less precipitation. The region around the Ratnagiri district in Maharashtra is especially known as a rain-shadow and drought-prone region.[54] The

[53] Stein, *Kalhana's Rajatarangini*: 200.

[54] See Spate and Learmonth, *India and Pakistan*, for the rainfall patterns in India and the two monsoons.

north-eastern monsoon brings some rains, mainly confined to Andhra Pradesh and eastern parts of Tamil Nadu. All of the rivers in peninsular India are entirely rain-fed; water is thus a precious natural resource, conserved and controlled from a remote Antiquity.

Karnataka too experienced the India-wide rise in land grant issuance. In an example from 904, describing the activities of a petty ruler in founding a village within a forest tract, paddy fields lay on the riverside and an excavated tank lay within the village. In the very next year, when a Brahmana donor created a rural settlement for immigrant Brahmanas, a huge tank fed by three streams from a nearby forest adequately served the newly established settlement, which may have grown after the clearing of a part of the forest.[55] In an eleventh-century example, a merchant (*sreshthi*) cleared another forest tract in Sorab taluk near a previously established *agrahara*, excavated a tank and laid out paddy fields.[56] These cases indicate a process that must have been occurring continually in the tenth and eleventh centuries. The result of these initiatives was, according to the inscription, demographic growth (*janodaya*).

Throughout Karnataka, the main form of local level irrigation was the artificial lake or tank, a category of public works designated as bunds aligned with natural sources of water (*sahodaka setu*), designed to trap runoff from rainfall. After 1000 one notes the construction of tanks with channels that were connected with rivers, described as bunds artificially fed with water (*aharyodaka setu*). Water managers regularly used sluices to control the inward and outward flow of water for these tanks. As early as 890, an inscription speaks of a tank with four sluices. Mention of the 'northern' sluice in another inscription from 1090 suggests the existence of more than one sluice in a tank. There are many epigraphic references to regular inspections and repairs of tanks and sluices. Boats were often employed to dredge the tanks, in order to maintain their capacity to hold water.[57] Though tanks were the principal means of storage of water in peninsular India, tanks in Karnataka had a special and individual feature in that most of these tanks formed a chain. The chain tank irrigation system ensured the filling up of tanks at a lower reach with the excess and overflowing water in tanks at a higher level. The natural contours

[55] *Epigraphia Carnatica*, vol. 10, Goribidnur Taluk 47.
[56] *Epigraphia Carnatica* , vol. 8, Sorab Taluk 317.
[57] Nandi, 'Agrarian Growth': 303–44.

and physiography of the land in the plateau region of western Deccan was thus integrated with hydraulic projects. An excellent example of this is available in the 'Big Tank' at Kattageri (Badami taluk, Karnataka) during the reign of Vikramaditya VI (1076–1126), the greatest ruler of the Western Chalukya dynasty. The method of draining excess water of a tank at a higher level was applied successfully here to fill up the tank at a lower level.[58]

As an outcome of these efforts to provide improved hydraulic resources, agrarian expansion and growth certainly took place in Karnataka. A clear illustration of this is seen in the perception of the *kanguda* variety of paddy. The *kanguda* type of paddy had earlier been viewed as an inferior type, while the *Manasollasa* of Somesvara III (twelfth century), considered the same variety as an excellent paddy (*sutandula*), fit to be included in the royal dietary practices.[59]

One may recall here once again the recognition of the regional variations in the hydraulic resources and projects in the vast subcontinent in the early medieval text, *Brhatkalpabhasyasutra*, already cited. The text in question impressed upon the importance of tanks as the principal hydraulic project, typically associated with the Dravida country, that is, the far south India, lying to the south of the river Krishna. The earliest Tamil poetry, the Sangam anthology, informs us of the five ecological divisions in ancient Tamilakam. These were *neidal* (agricultural tract), *marudam* (coastal area), *kurrinji* (forested mountainous area), *mullai* (pastoral zone), and *palai* (dry and arid tract).[60] Until the fifth century A.D. settlements in Tamilakam were mostly situated in the coastal and agricultural tracts. It is only during the post-A.D. 600 days that permanent agrarian settlements spread outside the *neidal* and the *marudam* ecozones. This became largely possible with the expansion of agriculture by issuing a large number of land grants, in other words, by local formation or the process from within.[61] The expansion of agriculture is inseparably intertwined with the enlargement of the irrigated area. As the far south does not possess many rivers of perennial nature, the spread of

[58] Srinivasan, 'Irrigation and Irrigation Works': 566.

[59] *Manasollasa*, 3, 1373–74. Quoted in Nandi, 'Agrarian Growth': 325–26.

[60] For the *tinai* as an ecological zone see Sivathamby, 'Early South Indian Society': 20–37; also see, Champakalakshmi, *Trade, Ideology and Urbanization*: 26–28.

[61] Gurukkal, 'The Beginning of the Historic Period'.

irrigation agriculture in that region largely depended on tank irrigation. Though this was, in many cases, an initiative of the village community, there are known instances of support for tank irrigation at the rulers' level. A few illustrations on this point will be in order.

The Pallavas of Tondaimandalam (north-eastern part of Tamil Nadu, including the northern part of the Coromandel coast) and the Cholas of Cholamandalam (core area being the Kaveri valley and the Kaveri delta) are particularly noted for excavating tanks of impressive size (Table 1).[62]

Table 1
Tanks in Tondaimandalam under Royal Patronage

Ruler	*Tank*	*Area/Dt.*	*Date*
Mahendravarman	Mahendratataka	North Arcott	600–30
Do	Chitrameghatataka	Chingleput	Do
Paramesvaravarman	Paramesvaratataka	Chingleput	670–700
Dantivarman	Kaveripakkam	North Arcott	796–847
Nandivarman III	Vairameghatataka	Chingleput	846–69
Parantaka I	Colavaridhi	North Arcott	907–55
Do	Viranameri	South Arcott	Do
Do	Nangavaram	Tirucchirappalli	Do
Do	Kalyaneri	Madurai	Do
Rajaraja I	Bahur	Pondicherry	985–1014
Do	Arikesarimangalam	Tiruchchirappalli	Do
Rajendra I	Cholagangam	Do	1012–44
Rajaraja III	Sembarambakkameri	Chingleput[63]	1216–60

Source: Agarwal and Narain (1997); Srinivasan (1997).

Royal inscriptions describing the construction of these tanks by the rulers' initiative also inform us about the sluices which were indeed meant for regulating and distributing the water from the tanks to cultivated fields. The Tiryaneri tank had 23 sluices, while the Viraneri tank had as many as 74 sluices.[64] Several sluices figure in the description of the Cholaganga

[62] The information about the enlisted tanks is available in Appadorai, *Economic Conditions in Southern India*; Minakshi, *Society and Administration*; Sastri, *The Colas*.

[63] The surviving remains of several pre-modern tanks and the politico-administrative instructions to ensure their maintenance are discussed with illustrations in Agarwal and Narain, *Dying Wisdom*: 242–311.

[64] Srinivasan, 'Irrigation and Irrigation Works': 566–67; for an elaborate discussion on the irrigation technologies and the use of sluices in south India see Gurukkal, 'Reservoir System of Irrigation', especially the illustrated discussion on *tumbu* (sluices) and *kumili* (sluice-pit).

tank in the Tiruvalangadu copper plate of Rajendra Chola. These channels, according to the inscriptions, were connected to irrigation channels. These sluices were dressed in granite slabs. The Sirgali sluice measures 35'× 8'. The existence of many sluices, possibly of an impressive size, in the tanks, speaks of the large size of the tanks themselves and the substantial area irrigated by them. Particularly notable are the Vairameghatataka of the Pallava times[65] and the Cholaganga tank made during Rajendra Chola's reign.[66] The inscriptions recording the excavations of the two tanks are further replete with elaborate and meticulous instructions to ensure optimum utilisation of the precious hydraulic resources. The Cholaganga tank was doubtless excavated to mark and celebrate the completion of the famous Gangetic campaign by Rajendra Chola (1024) during the course of which the irrepressible Chola army advanced as far north as Vangaladesa in the Ganga delta (Vangaladesa now denotes the Barishal–Bakarganj areas of Bangladesh). Rajendra claims to have brought the sacred water of the Ganga to the Chola heartland.[67] To mark this stupendous military achievement, Rajendra constructed the monumental Gangaikondacholapuram temple in Tanjore and assumed the political title Gangaikonda (captor of the Ganga). This was further accompanied by the excavation of the Cholaganga tank. 'This lord constructed in his own domain as a pillar of victory (a tank) known by the repute as Cholagangam which was composed of the water of the Ganges' (*Gangajalamayamjayastambham*).[68] While the account of the erection of pillars of victory by conquering kings is a pretty common element of the poetic eulogies in praise of rulers, the use of the metaphor of *jayastambha* to a royal tank is indeed a rarity.[69] It clearly underlines the special relation between the tank and its royal excavator/patron whose military and

[65] Sastri, *Studies in Cola History*: 120–23, 142–43.

[66] *South Indian Inscriptions*, III: 425, verse 24.

[67] For an account of this Gangetic campaign, see Sastri, *The Colas*: 208–34.

[68] Tiruvalangadu copper plate, see note 45.

[69] For a superb analysis of the Gangetic campaign of Rajendra Chola in the light of the Tiruvalangadu plates, see Ali, 'Royal Eulogy as World History'. Ali unravels the political ideology of Rajendra Chola's far flung campaigns, especially the Gangetic campaign. He however situates the eulogy in the Puranic ideals of world conquest (*digvijaya*) to which, he thinks, Rajendra Chola's conquests closely corresponded; in his analysis, Rajendra translated the Puranic ideals of universal rulership into practice and reality, though such far flung conquests did not always result in the expansion of the Chola realm. His persuasive reading of the text of the eulogy may provide a counterpoint to D.C. Sircar's position

political might the tank symbolises. The construction of the tank was something more than providing irrigation facilities, something beyond providing ritual purification in the vicinity of a monumental royal temple. The construction of the Cholaganga tank storing the sacred Ganga water, carried as it were by Rajendra to Cholamandalam as the crowning glory of a far flung campaign, is itself a political statement on the predominance of the Chola power.

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which looked at the royal eulogies as standardised hyperbolic claims that did not often match the actual area of control of these ambitious rulers. One may also ask here whether the Chola rulers, besides their aim for world conquest, territorial expansion and, to some extent, plunder, were not also interested in transforming a single valley (the Krishna) realm to a multi-valley political entity through conquests. For the maintenance and augmentation of the agrarian set up in south India, where perennial rivers hardly exist, valleys and deltas are often politically and militarily much sought after aims and gains.

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